Research article

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Bone Mineral Density Measured By Dual Energy X-Ray Absorptiometry: Results From A Cross-Sectional Survey In Children And Adolescents In Ho Chi Minh City, Vietnam

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Abstract

Introduction: Reference standards for bone mineral density (BMD) in children are not yet available in Vietnam. This study was conducted to quantify reference BMD values of children and adolescents in Ho Chi Minh City and to understand the associated factors.

Methods: A cross-sectional study was conducted on a convenience sample of 157 children and adolescents aged 6 to 17 in Ho Chi Minh City. DXA scans were performed to measure BMD at a hospital; anthropometric measurements, pubertal stages, and self-reported calcium intake were taken at schools. After that, the BMD of total less head (BMDTLH) and lumbar spine (BMDLS) by age, sex, or pubertal stage were established. Multivariable regression models were applied to determine associated factors with bone density.

Results: BMD increased significantly with the pubertal stages. Males' values were higher than those of females in both prepubescent and pubescent groups, except that in the pre-pubescent group, BMDLS values were nearly the same in both sexes. After adjustment, BMD was significantly and strongly associated with anthropometric variables but not dairy-based calcium intake.

Conclusions: The BMD data among Vietnamese children and adolescents and associated factors were found in this study, which could be beneficial for designing larger-scale studies.

Keywords: Reference, children; adolescents; bone mineral density; calcium

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1. INTRODUCTION

Osteoporosis and osteoporotic fracture have become significant public health problems. More than 10 million Americans and 27 million Europeans have osteoporosis, in which 1.5 million cases lead to fractures annually [1, 2]. Indeed, the situation in Vietnam is worth concerning, with 29% of postmenopausal women diagnosed with osteoporosis, which appears higher than in other Asian countries [3].

Despite occurring in older adults, osteoporosis commences in childhood [4]. During the growth phase, children's skeletons undergo a coordinated process between bone formation and destruction to allow bones to expand and lengthen into their adult form [5]. The deposition process makes bone mineral density (BMD) steadily increase. BMD peaks at around 16 in boys and 1 to 2 years earlier in girls, then decreases yearly [6, 7]. This means that osteoporotic risk dues to an inadequate accumulation of bone mass in adolescence and a decline in bone formation rate relative to bone resorption rate throughout the lifespan. Therefore, understanding characteristic of bone mass and its determinants in children and adolescents can help us prevent early osteoporosis from the early stage.

So far, we have learned that BMD is influenced by not only nonmodifiable factors (e.g., sex, age, race, gene, and puberty stage) but also modifiable factors (e.g., dietary calcium and vitamin D, and physical activity) [8-11]. Furthermore, many BMD reference data for children in Western countries (e.g., Netherlands and Sweden) and Eastern countries (e.g., China, Thailand, and India) have been developed [12-15]. Nonetheless, until now, no population-based studies have assessed BMD among children and adolescents in Vietnam. Using inappropriate BMD reference data can lead to over-, or worse, under-diagnosis and, hereafter, improper treatment. Eventually, this might well distort the actual disease burden at the national level. Large-scale and representative studies are essential to establish proper reference data. These kinds of studies require elaborate designs based on preliminary results.

Hence, this study aimed to quantify the BMD of 6-to-17-year-old children and adolescents stratified by sex, chronological age, and pubertal stage in Ho Chi Minh City. We also evaluated associations between BMD and sex, chronological age, puberty stage, anthropometric variables, and calcium intake from dairy products.

2. MATERIALS & METHODS

2.1. Study designs and participants

A cross-sectional study was conducted between 2018 and 2019 using a convenience sample of healthy children and adolescents in Ho Chi Minh, Vietnam. Children were excluded if having any either acute or chronic illnesses or using any medications relating to the alteration in body composition or bone minerals. One hundred and sixty five children and adolescents aged 6-17 (81 girls, 76 boys) from 5 schools (two elementary, two secondary, and one high school) participated in the study.

2.2. Data collection

Anthropometric measurement

We collected anthropometric data at the participant's schools. Weight (kg) and height (cm) were taken by electronic scale (Tanita HD-381) and portable stadiometer (Seca 213), respectively. Waist circumference (WC) was measured to the nearest 0.1cm with a non-elastic tape applied between the lowest rib cage and the iliac crest at the level of the umbilicus anteriorly. For the hip circumference (HC), the same measuring tape was used to check the hip perimeter in the area with the largest part of the gluteal region. All measurements were taken to the nearest 0.1 unit. BMI was calculated as weight (kg)/height (m2) and classified as overweight and obese using the 2007 WHO standard [16].

Puberty staging assessment

Female breast and male external genitalia development were determined by pediatricians using diagrams illustrating five of Tanner's stages [17]. Then, using WHO recommendations, participants were grouped into the prepuberty period (i.e., prepubescence) and puberty period (i.e., pubescence and post-pubescence) [18].

Calcium intake

Data on calcium intake were collected from two multiple-choice questions for each dairy product in a validated food questionnaire [19]: How many times and how much each time did you eat this food or drink milk? The first question had six answers: never, less than once a month, one to three times per month, once a week, two to six times per week, once a day, and two to three times per day; we converted these answers into numeric data as 0, 0.03, 0.07, 0.14, 0.57, 1.00, 2.50 (times/day). The second question had four options for four different portion sizes; we estimated the calcium ingredient for each portion size using Vietnamese Food Composition Tables in 2007. Daily calcium intake (mg/day) was equal to the calcium content in portion size multiplied by the amount consumed and frequency of having that food per day. Dairy products of interest included milk with or without sugar, cheese, butter, condensed milk, and yogurt.

Dual-energy X-ray absorptiometry (DXA)

BMD was measured and analyzed by DXA (Hologic Discovery QDR System) at 115 People's Hospital. Each participant was taken two scans: the whole body and AP lumbar spine (L1-L4) to measure BMD (g/cm2) following the recommendation of the International Society

for Clinical Densitometry (ISCD) [20]. We calibrated the DXA scanner daily by scanning a phantom to maintain its accuracy and precision.

2.3. Data Management and Statistical Analysis

Median imputation was used to compensate for missing values in the data set. The Shapiro-Wilk statistical test was used to determine whether the data were normally distributed. Results were presented in mean value with standard deviation. To compare between groups, we employed Student's t-test for continuous data, whereas for categorical data, we used the Chi-squared test. As the distribution of daily calcium intake was highly skewed, a non-parametric test (i.e., Wilcoxson rank-sum test) was used for group comparison.

Linear regression models in which BMD data were the outcome variable were applied to assess the associations between BMD and nutritional factors. Multivariate regression models were also employed to adjust for the effects of age, sex, and pubertal stages on the associations. We used R language version 3.6.3 to work with the data.

2.4. Ethical considerations

This study was approved by the Ethics Committee of Pham Ngoc Thach University of Medicine, approval number 2305/GCT-TDHYKPNT. Parents and children were informed about research information and were given a written consent form to sign up for participation.

3. RESULTS

3.1. Participants' characteristics

At first, 165 students participated in the study. Only 157 completed the data collection process and were ready for data analysis. The other eight students took DXA scanning but then refused to join the study due to the time constrains.

Table 1 shows that the boys, on average, were more dominant than the girls in anthropometric characteristics, with significantly higher body weight and overweight-obesity percentage (48.2 kg versus 42.4 kg and 64.5% versus 38.3%, respectively). Nonetheless, nearly twice as many girls reached puberty as boys. Also, the girls generally consumed more dairy-based calcium than the boys, although the difference was not statistically significant.

3.2. Bone density and its associations with other factors

The BMD data from Table 2 show an overall increment in both sexes across age groups. Although BMD in boys was lower than in girls at 6, they increased more remarkably across age groups and outnumbered girls at 17. In girls, the increase in BMD can be divided into two phases: total body less head BMD went up remarkably from 6 to 13 years of age but then seemed to level off until age 17. Similarly, after an increment from 6 to 15 years of age, lumbar spine BMD in girls began to reach a plateau. In boys, the same pattern was not seen. As they got older, the standard deviations increased in both total body less head and lumbar spine BMD.

For each pubertal stage, bone density in boys was larger than in girls at both whole body and lumbar spine scans (Table 3). Exceptionally, in the subgroup of prepuberty at the lumbar spine, BMD in girls outnumbered that of boys, though this was not statistically significant. Moreover, total body less head and lumbar spine BMD significantly increased when the children reached puberty in both sexes.

Table 4 indicates the findings of after adjusting for sex, age, and puberty stages. Overall, the associations between body indices with total body less head BMD were more pronounced than with lumbar spine BMD, with all regression coefficients being statistically significant. However, the calcium intake from dairy products did not have a significant slope, although it achieved good strength of association with BMDTBLH and BMDLS with R2 equal to 0.72 and 0.66, respectively.

4. DISCUSSION

Our study established a BMD values of the lumbar spine and total body less head from 157 children aged 6 to 17 by age, sex, and pubertal stage. Also, we found a positive association between anthropometric characteristics and bone density after accounting for age, sex, and pubertal stages. However, such a relationship was not observed between dairy-based calcium intake and bone density.

Besides, our findings had some common patterns with previous studies' findings [12, 15, 21]. The first is about the comparison of BMD between boys and girls. The values of whole-body scanning showed that the average BMD seemed to be higher in boys than girls in most age groups [12, 15, 21]. However, measurements from lumbar spine scanning indicated that girls' BMD values outnumbered boys' across age groups [15, 21]. The second point concerns the incremental characteristics of BMD in girls. Total body less head BMD in our study and Chinese study [12] saw two periods: the remarkable increase in the period of 6 to 13 years old and the rough levelling-off or decline in the later period of 14 to 17 years old. Concerning BMD at the lumbar spine, the turning point was 15 years of age when the incremental pattern changed to a relative plateau [15, 21]. Also, Annemieke et al. [21] and Pairunyar et al. [15] shared the same significant increase in BMD at the whole body and regional level when the children's pubertal stage went up. However, the Thai study witnessed no significant differences between boys and girls for each pubertal stages [15]. This contrasted with our study in which, apart from lumbar spine BMD in the prepuberty subgroup, there were significant differences between boys and girls at each pubertal stage.

Besides, our results were also consistent with the positive association between anthropometric indices and bone density in children and adolescents in previous studies [22] [23]. Indeed, some indices such as height, and weight were used in equations to predict bone mass or density [24, 25]. However, in obese female adolescents in Thai, the effect of waist circumference was attenuated, and no statistically significant association was observed [23]. Previous literature has shown mixed findings on this relationship concerning calcium intake and BMD. A study by Joo et al. in 2013 [26] showed that dietary calcium had no relationship with BMC in different scans in male adolescents in any age group. However, a significant association existed in a subgroup of girls from 10 - 13 years of age. Similarly, another study by Zhou et al. in 2016 [27] conducted on a youth cohort from 16 - 24 years old found no effect of calcium intake on BMD at the lumbar spine in both sexes, total hip and femoral neck in girls. A significant association did exist in boys at the total hip and femoral neck; however, this just happened in a very high calcium intake (>1,500 mg/day), and the result was not adjusted for other confounding nutrients such as dietary Vitamin D intake. This could be explained by the fact that calcium intake needs to reach a certain amount to affect bone density. A study by Wu et al. [28] concluded that calcium intakes to achieve maximal calcium retention were 1100 mg/day in boys and 970 mg/day in girls, while calcium intake from participants in our study was comparatively deficient, with the average 234.8 mg/day in boys and 244.7 mg/day in girls. A systematic review by Zhang et al. in 2017 [29] showed that significant positive effects of very high calcium intake on BMD and BMC for total body or specific sites were seen in 8/11 clinical trials in which high-dosed calcium diet regimes (>1,000 mg/day) were used. Nevertheless, the latest study in 2020 by Pan [30] et al. still found that a very high calcium intake (2.6 - 2.8 g/day) is associated with lower total BMD in black females from 12-15 years old.

As a strong point, we employed DXA - a reference method with high accuracy - to quantify bone characteristics. Also, our study covered a wide age range from 6 to 17 years to produce data for each age group. On the other hand, some limitations need to be taken into account. The first limitation is of some concerns about the DXA scanning procedure in young children. Some children, especially primary school boys, found it uneasy to lie still for at least 5 minutes for whole-body scanning. This led to the retake of the scanning or the dislocation of some body parts in the scanned image. Also, there was no proper equipment to maintain 90-degree hip and knee flexion in primary and early secondary school children, so the lumbar spine vertebrae might not be adequately exposed to the X-ray beam. Due to the problems above, errors could be introduced. Secondly, our study recruited a small and convenience sample. As such, when our results

were applied to design larger-scale studies, they should be inferred with a certain caution. Nevertheless, the standard deviations from the age-stratified BMD were relatively small and similar to previous larger-scale studies [12, 15, 21]. Therefore, our findings could be applicable for calculating sample size in further studies with larger scales. Lastly, the fact that the study estimated calcium intake only from diary products but not from total daily food consumes could have resulted in an underestimated association between calcium intake and BMD.

5. CONCLUSIONS

In summary, our study developed a BMD values of the total body less head and lumbar spine from a small sample of Vietnamese children and adolescents aged 6 to 17 years and their associated factors. This is the first study of its kind in Vietnam, and its results could be used to design larger-scale studies on bone characteristics of children and adolescents.

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CONTRIBUTION

TVK contributes to the study design, acquisition of data, data analysis, data interpretation, drafting, and review of the article; TMD contributes to the study design, acquisition of data, data analysis, data interpretation, and review of the article; DHL contributes to data analysis, data interpretation, and drafting the article; HKT contributes to study design, acquisition of data, data interpretation, review of the article, and makes final approval for submission.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Table 1. Descriptive characteristics of participants, means (SD) or N(%)

	Total (n = 157)	**Boys (n = 76)**	**Girls (n = 81)**
Age (year)	11.8 (3.2)	11.9 (3.2)	11.8 (3.2)
Height (cm)	145.5 (16.2)	147.4 (18.0)	143.7 (14.2)
Weight (kg)	45.2 (15.7)	48.2 (18.0)	42.4 (12.9)*
Waist (cm)	71.4 (11.4)	73.2 (12.1)	69.7 (10.6)
Hip (cm)	82.5 (12.8)	84.1 (12.6)	81.0 (13.0)
Obesity and Overweight	80 (60.0%)	49 (64.5%)	31 (38.3%)**
Puberty	98 (62.4%)	35 (46.1%)	63 (77.8%)***
Calcium intake from dairy products (mg/day)	239.9 (310.5)	234.8 (315.3)	244.7 (307.8)

** <0.05, ** <0.01, *** <0.001 boys vs. girls*

Table 2. Means (sd) BMD of total body less head (BMDTBLH, grams per cm^2) and lumbar spine (BMDLS, gram per cm^2) stratified by age and sex

Age	**Boys**			**Girls**		
	n	**BMDTBLH**	**BMDLS**	**n**	**BMDTBLH**	**BMDLS**
6	1	0.453	0.483	2	0.531 (0.032)	0.589 (0.082)
7	10	0.571 (0.037)	0.604 (0.048)	7	0.540 (0.041)	0.627 (0.069)
8	7	0.588 (0.033)	0.647 (0.039)	11	0.568 (0.066)	0.615 (0.103)
9	8	0.657 (0.072)	0.663 (0.097)	6	0.622 (0.070)	0.644 (0.107)
10	6	0.598 (0.058)	0.563 (0.063)	10	0.659 (0.072)	0.677 (0.088)
11	8	0.642 (0.066)	0.612 (0.076)	10	0.713 (0.069)	0.756 (0.115)
12	6	0.765 (0.098)	0.715 (0.150)	6	0.737 (0.073)	0.777 (0.097)
13	7	0.861 (0.090)	0.754 (0.134)	5	0.836 (0.110)	0.841 (0.102)
14	7	0.822 (0.101)	0.895 (0.104)	8	0.800 (0.054)	0.922 (0.129)
15	8	0.908 (0.084)	1.000 (0.106)	6	0.783 (0.029)	0.983 (0.083)
16	3	0.910 (0.111)	1.032 (0.138)	4	0.775 (0.034)	0.985 (0.076)
17	5	0.958 (0.069)	1.054 (0.100)	6	0.853 (0.087)	1.017 (0.111)

Table 3. Means (sd) BMD of total body less head (BMDTBLH, grams per cm^2) and lumbar spine (BMDLS, gram per cm^2) stratified by sex and pubertal stage

	n	**Total**	**n**	**Boys**	**n**	**Girls**
BMDTBLH	157	0.71 (0.14)	76	0.73 (0.16)	81	0.70 (0.12)
Prepuperty	59	0.60 (0.08)	41	0.62 (0.08)	18	0.56 (0.06)*
Pubertya	98	0.78 (0.12)	35	0.86 (0.12)	63	0.74 (0.10)***
BMDLS	157	0.76 (0.18)	76	0.75 (0.19)	81	0.77 (0.17)
Prepuperty	59	0.63 (0.08)	41	0.62 (0.08)	18	0.63 (0.09)
Pubertya	98	0.84 (0.18)	35	0.90 (0.18)	63	0.81 (0.17)*

** <0.05, ** <0.01, *** <0.001 boys vs. girls*

a: Significant difference (p<0.001) in total sample, boys, and girls

Table 4. Association of nutritional factors with BMD of total body less head (BMDTBLH, grams per cm^2) and lumbar spine (BMDLS, grams per cm^2)

	BMDTBLH				**BMDLS**			
	βx10-3	**R2**	**Adjusted βx10-3**	**R2**	**βx10-3**	**R2**	**Adjusted βx10-3**	**R2**
Weight (kg)	7.5^{***}	0.72	4.3^{***}	0.82	8.0^{***}	0.47	3.3^{***}	0.69
Height (cm)	7.6^{***}	0.78	5.5^{***}	0.79	8.7^{***}	0.60	4.6^{***}	0.69
Waist circumference (cm)	7.9^{***}	0.42	3.5^{***}	0.78	7.5^{***}	0.22	2^{*}	0.67
Hip circumference (cm)	8.4^{***}	0.59	3.6^{***}	0.78	9.2^{***}	0.41	2.7^{**}	0.67
Dairy-based calcium intake (100 mg/day)	0.1^{**}	0.04	1.9	0.72	0.1^{*}	0.02	0.4	0.66

** <0.05; ** <0.01; *** <0.001*

β: regression coefficient

R2: Adjusted coefficient of determination